Analysis of Tire Rub Rail Interaction

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Abstract

On December 20, 2010, a Mine Safety and Health Administration (MSHA) inspector issued a citation at a mine site because the side railings on the drive-over-scale were not mid-axle height of the largest piece of equipment to use the scale. The side railings were 5 inch diameter tubing with the top of the rail 10 inches high. HVE SIMON was used to model the interaction of a tractor-trailer and a straight truck with the side railing. Based on the speed of trucks on the scales, the method of operation on the scales, truck dynamics and driver control, the HVE analysis revealed that the height of the side rails on the subject scale was sufficient to give feedback to the driver and keep the truck on the scale. The MHSA judge agreed with this analysis and dismissed the citation.

Background

Knife River Corporation (KRC) operated a mine at the MBI Portable #1, mine ID 35-03321. A truck scale was at the mine site to weight the trucks as they come and go from the mine to determine the amount of material each truck carried (**Figure 1**). Trucks only traveled in one direction over the scale and at very slow speeds. The scale was equipped with side rails that were 5-inch diameter tubing with a top height of 10 inches. To the right of the scale was an approximately 41-inch drop-off (**Figure 2**).

Figure 1: Approach to scale.

Figure 2: Side rail and drop off.

In the MSHA inspector's opinion the scale constituted a roadway; therefore, 30CFR56.9300 "Safety devices, provisions and procedures for roadways, railroads, and loading and dumping sites" applied. 30CFR56.9300(a) and (b) state:

(a) Berms or guardrails shall be provided and maintained on the banks of roadways where a drop-off exists of sufficient grade or depth to cause a vehicle to overturn or endanger persons in equipment.

(b) Berms or guardrails shall be at least mid-axle height of the largest self-propelled mobile equipment which usually travels the roadway.

The mid-axle height of the largest vehicle to use the scale was 20 inches. Therefore, the inspector wrote the citation because the side rails were only 10 inches high. The mine could not use the scale until the side rails met the provisions of 30CFR9300. The mine company decided to appeal the citation on the basis that the side rail prevented the truck traffic from going off the scale due to the slow speeds and the fact the trucks had to stop twice on the scale, preventing them from traveling more than 5 mph across the scale.

The task at hand was to model the interaction between a commercial vehicle and the side rail if the commercial vehicle rubbed against or even slightly turned toward the rail. The goal was to determine the potential of a commercial vehicle going over the side rail at speeds typically driven on the scale.

Vehicles

The Freightliner Columbia from the EDC vehicle database was used as both a straight truck and towing a trailer. As a straight truck the weight was increased to 50,000 pounds. The default tire model for all the tires was a generic "Heavy Truck" tire. The EDC database had a Michelin X 11.00R20 tire. To change all the tires, left click on a tire and chose "Tire…". Check the "Copy To Other Side" and "Copy To Other Axles(s)" check boxes. Under the Manufacturer dropdown box, chose the tire manufacturer (**Figure 3**). All the tires on the Freightliner were changed to this tire. The default suspension was used.

The 48 foot Wabash Flatbed trailer from the EDC vehicle database was used for the trailer. The center of gravity (CG) of the trailer was raised and the weight increased to 60,000 pounds to model a loaded trailer. To change the CG, left click the mass and chose "Move CG…". Next enter the changes to the CG location. Since the SAE coordinate system defined the vehicles, a negative value for dz raises the CG (**Figure 4**).

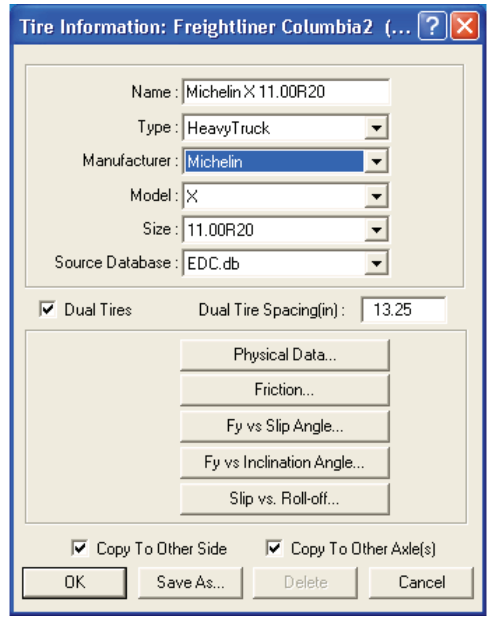

Figure 3: Changing the tire.

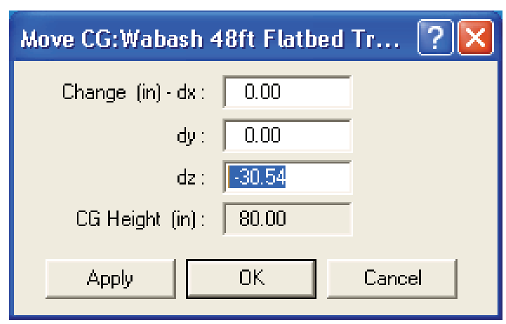

Figure 4: Changing the CG Height.

An accelerometer was placed in the approximate location of a driver. The accelerometer measured accelerations in the longitudinal, lateral and vertical directions.

Accelerometers are added in the Event Editor. After the vehicle of interest has been positioned, select the vehicle. Under the Set-up menu chose Accelerometers. The Accelerometer Data window for that vehicle opens. Check the "Device In Use" check box to turn on an accelerometer. Then enter the location of the accelerometer in the coordinate boxes (**Figure 5**). The coordinates are relative to the vehicle's CG and follow the SAE convention.

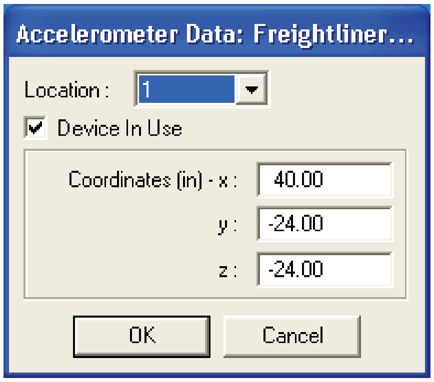

Figure 5: Adding accelerometer to Freightliner

Building the Environment

The scale is modeled as a flat asphalt surface 41 inches high. A cylinder is used to make the side rail. When in the Environment Editor, chose "Launch 3-D Editor" under the "3-D Edit" menu. Click the "Cylinder" button to create a cylinder (**Figure 6**). The dimensions for a cylinder are in feet. The Radius defines the radius of the cylinder, in this case 0.21 feet (5 inches diameter). The Height Z(ft) parameter defines the length of the cylinder. By default a cylinder is centered at the global 0, 0, 0 coordinate and is along the Y-axis. The coordinate values move the center of the cylinder, again using SAE convention. The Angle entries are used to define the direction of the cylinder. The side rail is a 5-inch diameter cylinder with its center 7.5 inches above the asphalt surface (4.04 feet above the ground), making the top of the cylinder 10 inches above the scale surface. **Figure 7** shows the environment model with the truck at the start position for the simulations.

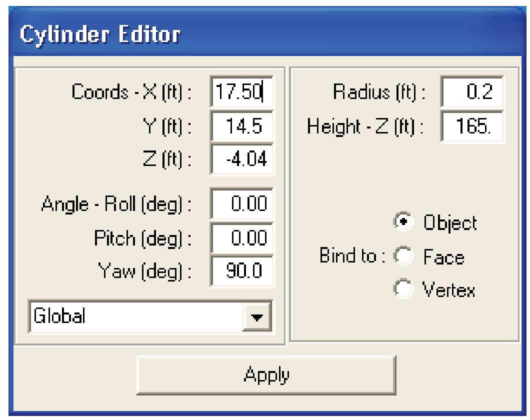

Figure 6: Cylinder Editor dialog.

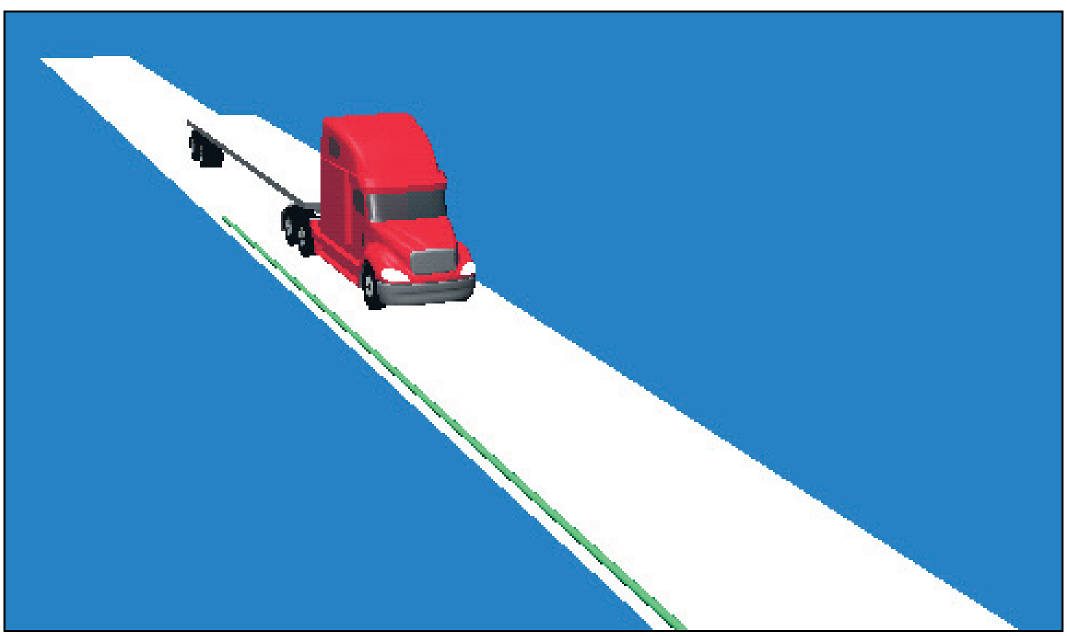

Figure 7: Environment and truck at start of simulation.

Event/Simulation Settings

The Point Contact Tire-Terrain Model was used for the left tires. However, the Point Contact model caused an event termination error for excessive wheel deflection when the right-front tire started interacting with the side rail. Therefore, the Radial Spring model with Sidewall Impact turned on was used for the right tires. The default settings for the radial springs were used (**Figure 8**).

Based on conversations with the mine operators, trucks traveled across the scale at less than 5 mph because they had to stop on the scale twice; once in the middle of the scale to get weighed and once near the end of the scale to pick-up the weight ticket. To be conservative, vehicle speeds of 5 and 7 mph were used. The front wheels were turned to the right at 3, 5 and 10 degrees to model a vehicle moving toward the side rail. To model a driver's reaction to contacting the side rail, the front wheels were turned to a left steer angle of 15 degrees when the driver's location experienced a 0.1 g lateral acceleration from the right steer tire contacting the rail. The accelerometer placed in the Event Editor was used to determine when the "driver" experienced this acceleration. The steer angle was changed over 1 second (**Figure 9**). For the 7 mph, 10 degree steer angle simulation, the clutch was also disengaged when the driver felt the 0.1 g lateral acceleration. This was accomplished by reducing the throttle to zero in the Driver Controls window. The brakes were not applied in any of the simulations.

Simulations

Table 1 summarizes the simulation results. The simulations demonstrated that the height of the side rails on the subject scale was sufficient to give feedback to the driver and keep the truck on the scale. In the worst cases, the right-front tire partially climbed the rail; however, the truck either stopped due to friction between the tire and rail, or it drove back toward the center of the scale platform (**Figure 10**). As stated above, a 5 degree steer angle on a scale platform would be very high and only occur with intentional driver action. At 5 mph or less on a scale platform, steering angle corrections would be expected to be very small (less than 3 degrees). At a steer angle of 3 degrees the right-front tire did not climb the rail but scuffed along the rail until the truck stopped from the tire sidewall friction against the rail (**Figure 11**). Other simulations were run with a 50,000 pound straight truck; however, the truck did not go over or even on top of the rail, but was always redirected back toward the center of the scale platform.

Based on the speed of trucks on the scales, the method of operation on the scales, truck dynamics and driver control, the HVE analysis revealed that the height of the side rails on the subject scale was sufficient to give feedback to the driver and keep the truck on the scale. Based on the number of trucks that had traveled over the scale without an incident and the HVE simulations, the probability of a truck going over the side rail was insignificant.

On May 5, 2011, an MSHA hearing was held in Portland, Oregon. After all the testimony and presentation of the simulations, the MHSA judge agreed with this analysis and dismissed the citation.

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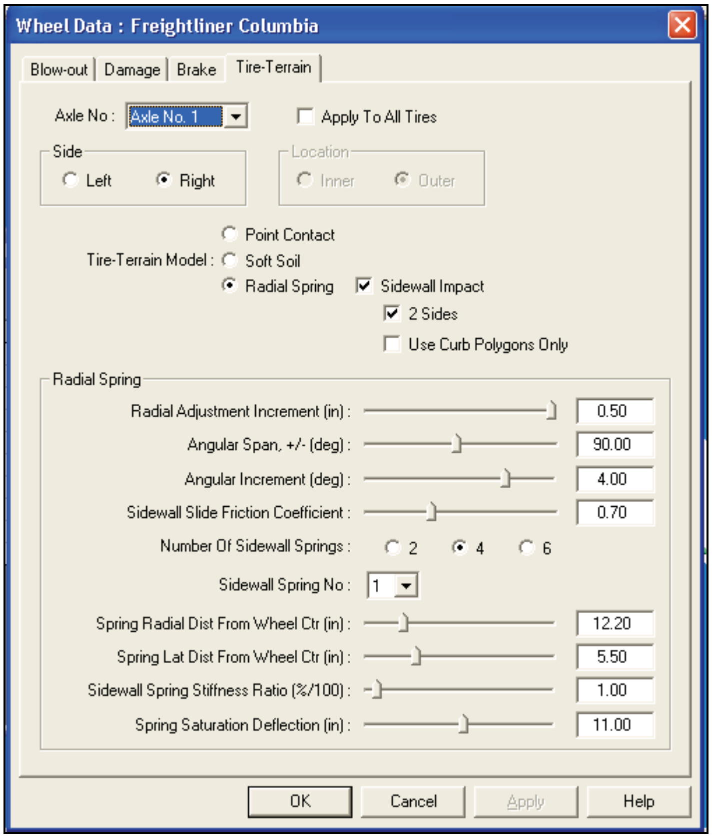

Figure 8: Wheel Data dialog.

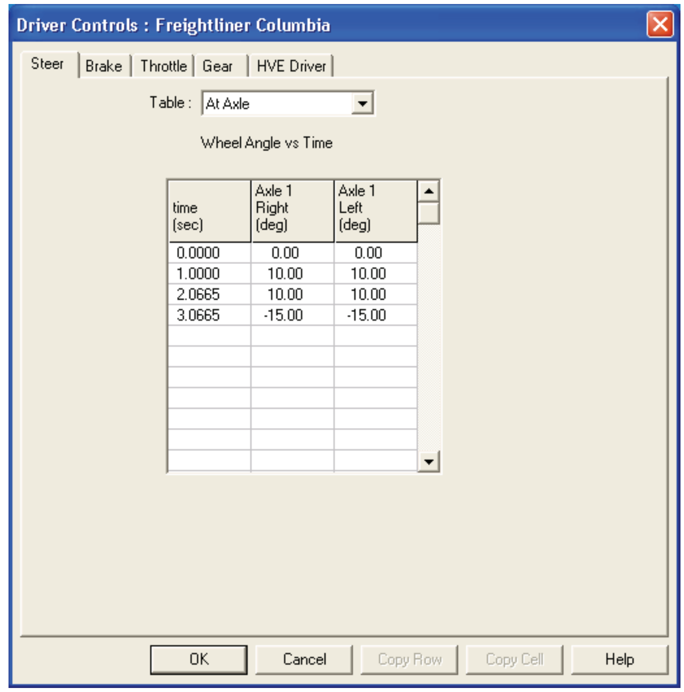

Figure 9: Typical Steer Table.

Table 1: Simulation Results.

Speed (mph)	Steer Angle (deg)	Clutch Disengaged	Result
5	3	No	The right-front tire did not climb the rail but scuffed along the rail until the truck stopped from the tire sidewall friction against the rail.
5	5	No	Depending on the starting conditions, the truck was either redirected back toward the center of the scale platform or the right-front tire rubbed enough on the rail to stop the truck.
5	10	No	Depending on the starting conditions, the truck partially climbed the side rail and either stopped due to friction between the rail and tire or came off the rail and drove back toward the center of the scale platform.
7	3	No	The right-front tire did not climb the rail but scuffed along the rail until the truck stopped from the tire sidewall friction against the rail.
7	5	No	The right-front tire partially climbed the rail and then came off the rail and drove back toward the center of the scale platform.
7	10	Yes	The right-front tire partially climbed the rail and then came off the rail and drove back toward the center of the scale platform.

Figure 10: 7 mph, 10 degree steer angle with tire on top of rail.

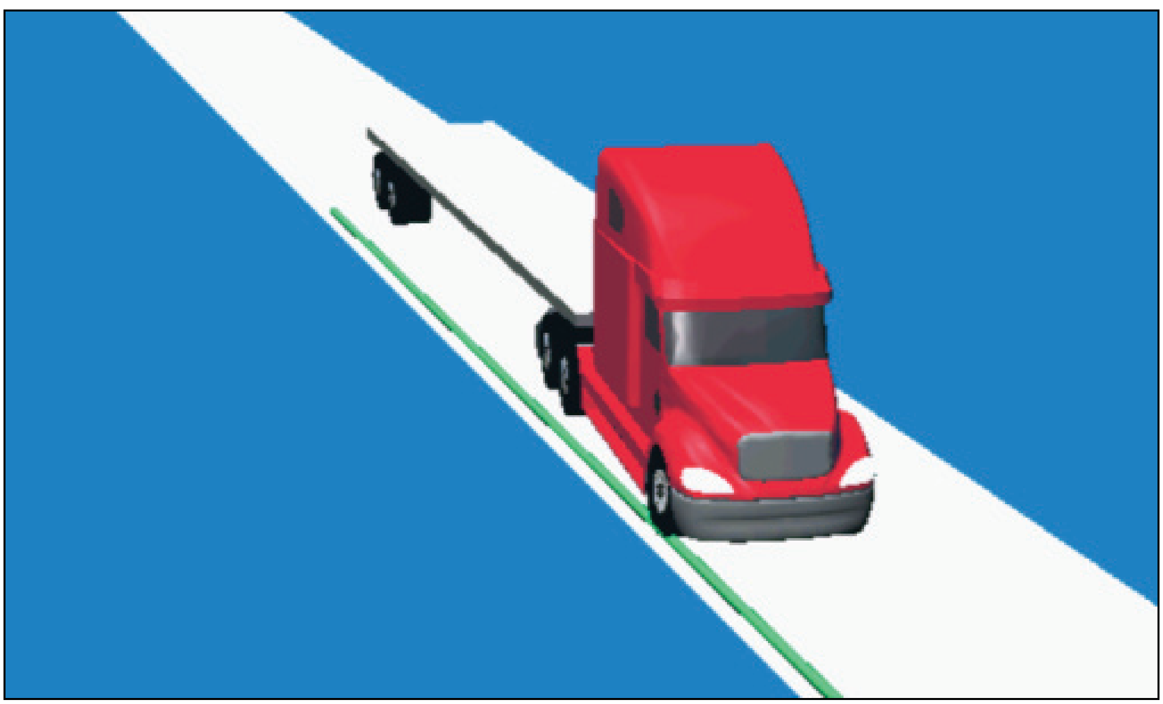

Figure 11: 5 mph, 3 degree steer angle, truck at rest against rail.